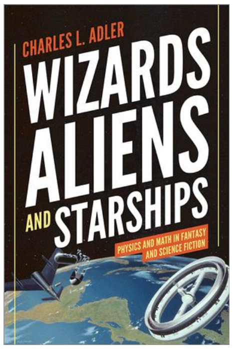
Wizards, Aliens and Starships, physics and math in fantasy and science fiction. by *Charles L. Adler*. Princeton University Press, 2014, ISBN 978-0-691-14715-4 (hbk), 378 pp.



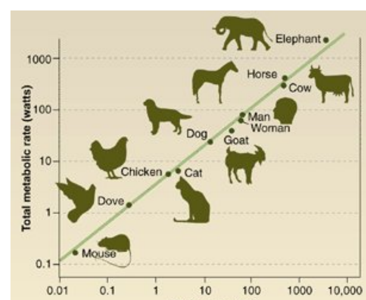
Charles L. Adler

If you are a Harry Potter fan, did you ever believe that it was true that a person can be transformed into a ferret? Did you believe that dragons and monsters exist in real life? Or that people can just disappear? Probably not. Did you ever think of a reason why it is impossible? You've never seen it happen, but that is no reason why it is impossible. Adler gives some good reasons from first principles. If a person of 60 kg is transformed into a small animal of 2 kg, then a mass of 58 kg is gone. Physics conservation laws tell us that it must have been transformed into energy, and with Einstein's formula $E = mc^2$ this would be a hell of a big bang because the Hiroshima bomb is about the equivalent of 1 gram of matter. As much energy is required to undo the spell. Teleporting suffers of the same problem. "Beam me up Scotty" is not a sentence that will be spoken for real in our universe. Harry Potter's *reparo* evokes a mending charm to repair broken things or undo a chaotic situation. Again quite unlikely without the necessary energy because it is violating the second law of thermodynamics.

The *Hogwarts School of Witchcraft and Wizardry* being lit by thousands and thousands of candles floating in midair would make it still a very dark place. Adler computes the luminous efficacity of candles and it turns out to be miserable, not to speak of the cost of replacing the candles, and of all the dripping.

Similarly, Kleiber's law relates body weight and metabolism, and because the energy needed to fly is related to metabolism, this imposes an upper bound of about 20 kg for the largest possible biological fliers. Thus no large flying dragons can ever exist without engines.

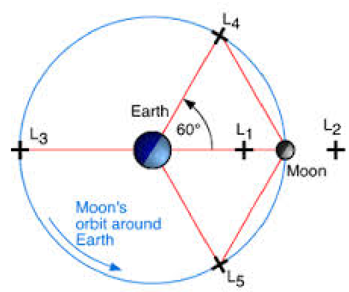
Hogwarts lights



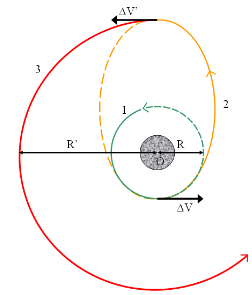
Kleiber's law

This is the way Adler deals with magic and witchcraft in the first part of this book. With basic physical laws and some elementary computations, the impossibility of certain phenomena is actually proved. The main part of the book deals however with science fiction. This genre is obviously the place where (pseudo) science is an essential part of the plot. The most extensive part of the book deals with space travel. More speculative is the search for and the design of extra-terrestrial worlds. The last part takes a glimpse at the distant future of humanity in the stellar system and the possible cosmological endings.

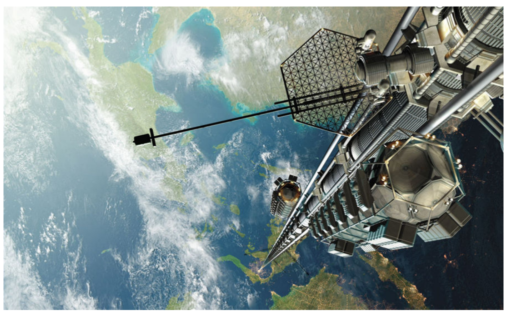
Let's start with space travel. For the moment we are using rockets with chemical fuel burning propulsion to leave the earth. The technology did not change too much since its origin which is very much unlike the spectacular evolution of computers. Adler explains why. Cruising the nearby space raises energetic problems. For every gram brought into space there is an enormous overload for fuel needed. Space colonies of some 10,000 people have their own problems of providing breathable air, food and water, and gravity. Moreover one has to find a good spot to build it if it should be in an orbit around the earth. This forces us to choose the Lagrange points which are positions that give periodic solutions in an otherwise chaotic three body problem with the earth and the moon. But why would one do that in the first place? Mining or the special conditions for production are often used as an argument, but a simple financial calculation makes this rather unlikely to be profitable. If rocket launching is too expensive, and if a station is up there, then why not instal an elevator. Some calculations also put a limit to that. A tower on earth is excluded because the basis it requires would be far too wide, and when it ‘hangs’ from the station then there is a limit to what will not collapse under its own weight. The furthest one gets in this line of thought is carbon nanotubes. For interplanetary travel, Adler works out the currently used physics of the Hohmann transfer orbit where the space ship leaves one smaller planetary orbit to join a larger one. Possibly use can be made of the gravitation of intermediate planets with a slingshot effect.



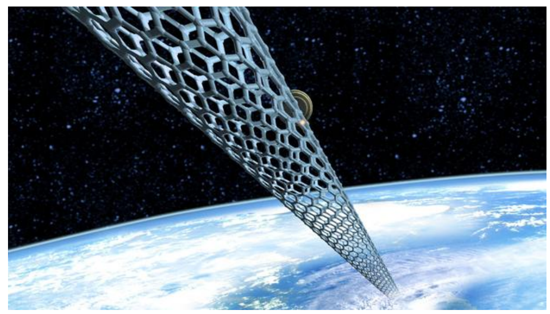
Lagrange points L_1–L_5



Hohmann transfer orbit

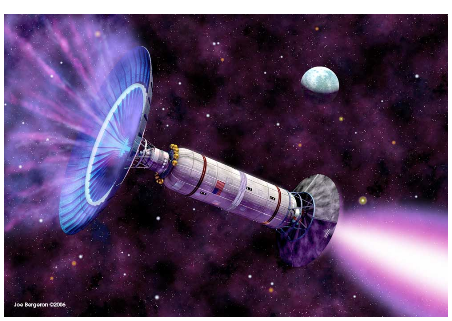


space elevator



carbon nanotube elevator

But if we are traveling farther away from home, then it’s not only a matter of getting there but also of getting there during a human lifetime, and then other propulsion systems are in order. In that case burning will not be enough. Nuclear power is one possibility that was taken up by NASA in the 1960’s. The problem is how to use it. An enormous amount of energy is delivered in a very short time which would squeeze the astronauts to jelly unless it can be controlled. The Bussard ramjet is an alternative. The idea is that it scoops up the atoms in space to be used as fuel in a fusion engine. Matter-antimatter use is a speculative alternative, which would cause a serious radiation problem. For interstellar travel, we should be able to accelerate to almost the speed of light, by constant acceleration while leaving, and constant deceleration before arrival. Of course relativity theory will play an important role. One chapter deals with travel faster than light (FTL). According to general believe and ample evidence, this is impossible, but suppose it were, then it would also be possible to travel in time, with problems of what is the cause and what is the consequence since notions of first and last become relative. This is also the chapter where Adler explains about black holes, wormholes are exotic matter.

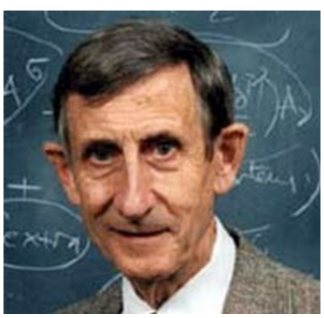


Bussard ramjet

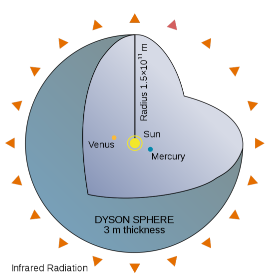
In the third part of the book, Adler considers alternative places where humans could live. First he computes an acceptable distance of an earth-like planet from its star. Given the number of stars, there is a large number of such planets. However, this is not the only condition for life to be possible. It is the whole history of the planet that has to be taken into account. Given a star of a proper size, and a planet at a proper distance, it needs atmosphere, a solid soil, the right temperature changes, right orbital eccentricity, etc. and it is not excluded that accidents in the history like the impact that we experienced when our dinosaurs were wiped out had as a consequence that we humans got the chance to develop to what we are now. But still, suppose there are some planets with all these properties, how are we going to find them since they are dark objects near bright stars? There are appropriate techniques for doing that as Adler explains. He also makes a model of which civilisations of aliens would be able to make contact and why they would ever want to contact us or explore space. The SETI project is *Searching for ExtraTerrestrial Intelligence* but it has not been successful till now.

SETI antennas

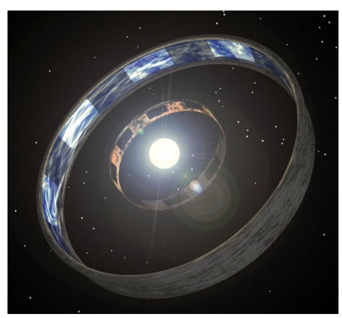
The last part is a view of what lies waiting for us out there in the distant future. Of course that is if we survive our immediate treads like global warming, nuclear war, the end of oil resources, etc. Can we then build a new home somewhere else? For example when our sun is growing in a later stage. Take for example Venus or Mars. Then we need to generate soil, to manage the temperature, to generate oxygen etc. Several other much more ambitious projects have been proposed. If in an even later stage of our sun it is cooling down, Freeman Dyson has proposed to build a sphere around the sun. That is a shell of 3 m thick and with a radius of 1 astronomical unit (= distance sun-earth) to catch all energy that it is still radiating. This would need enormous quantities of mass, for which we would need to tear apart the planets in our solar system. Another possibility is the Ringworld of Larry Niven. That is a ribbon instead of a sphere, however Adler's computations show that this would require more mass than the sphere. A manifest problem is the stability of such structures, both dynamic and static. Such enormous projects require civilisations that can be classified on the *Kardashev scale*. A type I civilization can use the energy of its entire planet, type II can use the energy of its star and type III the energy of its galaxy. Our civilisation ranks as type 0.7 approaching type I. The Dyson sphere or the Niven ringworld would require a type II civilization. That type would also be able to move the earth to a different orbit. In a last chapter, Adler gives an idea what could happen at the very end. In the 'short term' ($\approx 5 \cdot 10^8$ years) we might expect for example another astroid impact of the type that wiped out the dinosaurs, on a 'medium level' (up to 10^{13} years) we could perhaps move the earth, and in the 'long term' vision, the universe may consist of only black holes which may eventually evaporate.



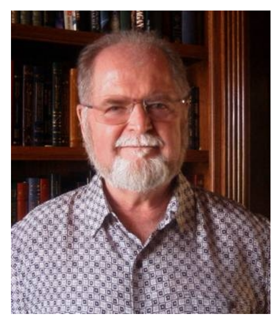
Freeman Dyson



Dyson sphere



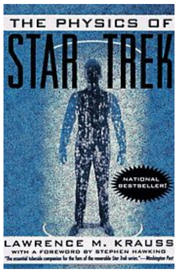
Niven ringworld

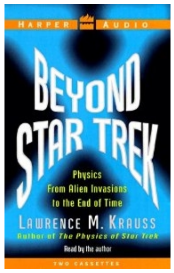


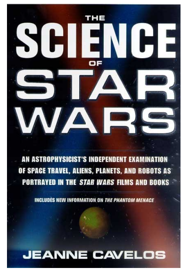
Larry Niven

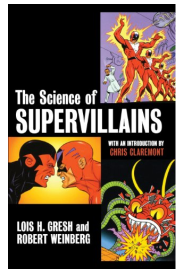
Working through this book brings you down to earth from the adventure story you are reading by explaining what is possible and most of the times what is not and it gives good reasons why. On the other hand, it discusses also topics that go beyond your wildest dreams as an SF adict. The scale of the problems makes you dizzy with very long sequences of zeros pushing some digits into oblivion. With a little bit of feeling for physics and for mathematics, it provides a wonderful playground inviting for further exploration. A Disneyworld where fantasy and SF are brought down to earth. And as a bonus, you get some guide to the SF literature and films: Arthur C. Clarke, Philip K. Dick, Ursula Le Guin, Robert A. Heinlein, Larry Niven, Star Trek, Babylon 5, Star Wars, Avatar,... and many other delicatessen.

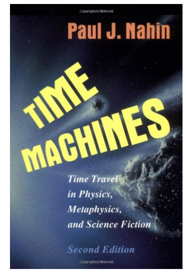
Note however that this is not the first book devoted to these subjects. The science of fantasy and science fiction, is not the final frontier. Where this author goes, many others have gone before. See the list below which is just a sample because there are many more and there are many websites dealing with these subjects.

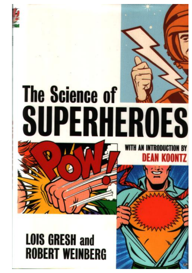


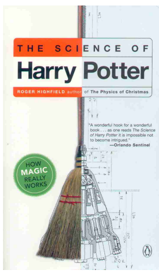


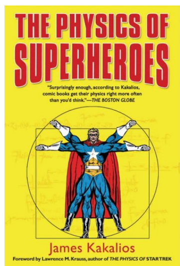


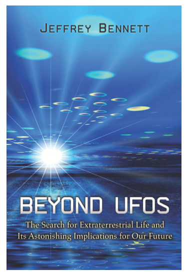


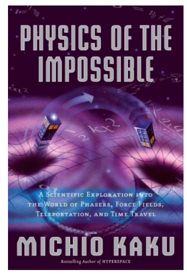


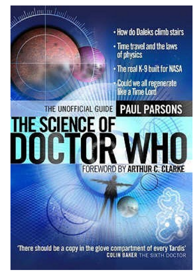


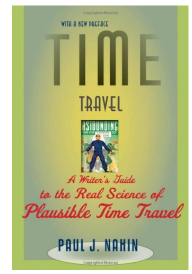












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